COUNTER-BORED FILM-COOLING HOLES

BACKGROUND OF THE INVENTION

[0001] This invention relates to the configuration of film-cooling holes utilized as part of the cooling circuit in the airfoil portion of a turbine blade or bucket.

[0002] Film-cooling has been a major aspect of gas turbine cooling for many years. The application of effective film-cooling techniques provides the first and best line of defense for hot gas path surfaces against the onslaught of extreme heat fluxes, serving to directly reduce the incident convective heat flux on the surface. As film-cooling holes first go into service, they are typically cleaned of all obstructions or unwanted debris. Film holes in this condition may also include certain protective coatings, either diffusion or thermal barrier coatings (TBC), for such purposes as oxidation protection. In operation, film holes and hot gas path surfaces see a multitude of conditions and environments which can result in the sudden or gradual blockage of holes to various degrees, thereby influencing the film-cooling performance to lesser or greater extents.

[0003] It has been discovered, however, that as a TBC coating is sprayed on the airfoil of the bucket, some of the coating material enters the exit of the film-cooling holes. Thus, the TBC adheres to the inside surface of the film-cooling holes, decreasing the effective exit area of the holes and reducing the film-cooling effect from the design intent.

BRIEF DESCRIPTION OF THE INVENTION

[0004] The present invention solves the partial obstruction of film-cooling holes due to TBC's sprayed on the airfoils of the buckets by changing the configuration of the film-cooling holes to include a counter-bore at the outlet or exit ends of the film-cooling holes. It is contemplated that the counter bores would be applicable to the holes along the leading edge shower head, gill holes and the holes around the bucket tip region. The counter-bore diameter and depth are specific to the design, and have been optimized for performance. For example, in one exemplary embodiment, a counter-bore of 0.053 inches on a 0.033 inch diameter through-hole extends 0.03 inches from the outlet surface of the airfoil on the minimal dimension.

[0005] The general concept of incorporating a counter-bore or flared shape can be applied to all film-cooling holes for various gas turbine buckets, nozzles and shrouds with TBC application on those parts.

[0006] Accordingly, in one aspect, the invention relates to a turbine component having a plurality of film-cooling holes formed in a region of the component to be cooled, the cooling holes having specified diameter, each hole at an exit thereof formed with a counter-bore of predetermined depth; the component having a coating applied thereto at least in the region, wherein the counter-bore provides an area for excess coating material to accumulate without reducing the specified diameter.

[0007] In another aspect, the invention relates to a gas turbine bucket having an airfoil portion and a shank portion, the airfoil portion having a plurality of film-cooling holes therein, each hole at an exit thereof formed with a counter-bore of predetermined depth; the component having a coating applied thereto at least in the region, wherein the counter-bore provides an area for excess coating material to accumulate without reducing the specified diameter; and wherein the coating comprises a first bondcoat layer and a second thermal barrier coating layer.

[0008] In still another aspect, the invention relates to a method of maintaining cooling efficiency of film-cooling holes in a turbine component where the film-cooling holes have specified diameters and the turbine component has a protective coating therein comprising: a) before coating, forming each film-cooling hole with a counter-bore and an exit end of the film-cooling hole; and b) spraying the coating onto the turbine component at least in areas surrounding the film-cooling holes such that excess coating material accumulates in the counter-bore without reducing the specified diameter of the cooling holes.

[0009] The invention will now be described in detail in connection with the drawings identified below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIGURE 1 is a perspective view of a gas turbine bucket with film-cooling holes along the leading edge of the bucket airfoil; and

[0011] FIGURE 2 is a sketch through the centerline of a film-cooling hole in a test plate showing the build-up of a TBC coating in the hole; and

[0012] FIGURE 3 is a cross section view of a film-cooling hole on the leading edge of a bucket in accordance with one embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0013] Referring now to Figure 1, there is illustrated a turbine bucket 10 constructed in accordance with the present invention including an airfoil 12 mounted on a platform 14. The turbine bucket also includes forward and aft wheel space seals, i.e., angel wings 16, 18, respectively. The buckets 10 are adapted for mounting on the turbine wheel in conventional fashion. The airfoil 12 has a profile including a compound curvature with pressure and suction sides 20, 22, respectively, as well as a leading edge 24 and trailing edge 26.

[0014] It is known to apply a thermal barrier coating (TBC) to various regions of the bucket including adjacent the leading edge 24. Typical TBC's include a first bondcoat layer and a second ceramic coating layer. The bondcoat layer may be an NiAl-based bondcoat, and the thermal barrier coating layer may be a yttria-stabilized zirconium layer. It is also known to provide film-cooling holes 28 in various regions of the bucket including but not limited to the leading edge 24. Figure 1 illustrates a few representative film-cooling holes 28 for purposes of ease of understanding of the invention.

[0015] Figure 2 is a sketch of a conventionally-shaped film-cooling hole 28 formed in a test plate along a simulated leading edge 24. It can be seen that excess TBC material 30 that coats the simulated leading edge area accumulates within a portion of the hole 28, resulting in a decreased effective diameter of the hole at the outlet thereof. In a real cooling hole on a bucket, this condition decreases cooling efficiency.

[0016] Figure 3 illustrates in detail one example of a film-cooling hole in accordance with the invention. Film-cooling hole 32 is shown to be located at the radially outer end of a bucket 34, along the leading edge 36. The film-cooling hole has a nominal diameter "d" that extends outwardly from an internal region 38 of the bucket. In accordance with the invention, film-cooling hole 32 is counter-bored to a diameter "d_1" from its outlet on the leading edge 36 inwardly to a predetermined depth "h." In a typical example, the nominal diameter d of the film cooing hole 32 is 0.033 in. For this size cooling hole, the counter-bore 40 has been formed with a diameter d_1, of 0.053 in. It will be appreciated that the dimensional relationships and dimensions themselves may be varied to suit different size buckets. It will further be appreciated that the invention is applicable to cooling holes in any areas on any components that are coated. The counter-bore will provide adequate space to accommodate excess TBC coating material without reduction of the effective cooling flow.

[0017] While the invention has been described in connection with what is presently considered to be the most practical and preferred embodiment, it is to be

understood that the invention is not to be limited to the disclosed embodiment, but on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.